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Mr. A. E. Conrady, Mr. R. Inwards, and Mr. G. J. Newbegin were appointed auditors of the Treasurer's accounts for 1906.

Eighty presents were announced as having been received since the last meeting, including, amongst others :—

Abbadia Observatory, Observations, tome 5; and Bordeaux Observatory, Catalogue photographique du ciel, Coordonnées rectilignes, tome 2, presented by the Observatories; Gronnigen Astrographical Laboratory, Libration of the three inner large satellites of Jupiter (W. de Sitter), presented by the Laboratory; Ziegler Polar Expedition, Scientific results, presented by the estate of Wm. Ziegler.

Astrographic Chart; 16 charts presented by the Royal Observatory, Greenwich; and 19 charts presented by the French Minister of Public Instruction.

Solar Parallax Papers. No. 6.

Construction of a Standard Catalogue of Photographic Star Places. By Arthur R. Hinks, M.A.

§ 1. The construction of a standard catalogue of photographic star places along the track of the planet Eros was undertaken in the first instance to provide for the reduction of those series of photographs of the planet which, having a field smaller than 2° square, could not be reduced directly with the *étoiles de repère*; and also to provide exact places of the stars which had been used in visual micrometric comparisons with the planet.

It now seems probable that the standard catalogue may have an extended use; for, as will be shown later, it will be possible by its aid to effect very simply the equivalent of a re-reduction of all the published places of the planet to this new system of stars, lying close to the track of the planet, and more nearly equal to it in magnitude than are the *étoiles de repère.* This should provide a powerful method of searching for systematic errors in the photographic places of the planet and the value of the Solar Parallax derived from them.

§ 2. The published material for the construction of the catalogue was found in the Paris Eros Circulars, Nos. 10 and 11.* The results of an inter-comparison of the work of the different observatories were published in *Solar Parallax Papers* Nos. 4 and 5 (*M.N.*, vol. lxvi. p. 481, vol. lxvii. p. 70, 1906 June and November). In those papers may be found the following conclusions :—

(1) That several series of photographic star places are affected with a magnitude equation of serious amount.

(2) That other series are affected by progressive discordances,

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* Circular No. 12 appeared after the principal part of the work was finished. But see later, §§ 11 and 12.

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which are sometimes dependent on variations in the adopted places of the fundamental stars, and sometimes not.

(3) That, in general, the star places published in the Paris Circulars are by no means homogeneous.

(4) And that the adopted form of publication did not permit of a complete inquiry into these matters.

§ 3. In 1906 March I ventured to send to the Directors of the observatories concerned a circular letter, submitting for their consideration the following proposals:—

That I should print and distribute a large number of lists of the *étoiles de repère.*

That they should kindly undertake to fill in upon those sheets, in the spaces provided for the purpose, the deduced photographic places of the *repère* stars, using a separate list for each plate, so that the results from each individual plate were kept quite distinct.

That they should also fill in, upon other sheets to be provided for the purpose, the lists for each separate plate of the deduced places of the *étoiles de comparaison* (given in Paris Circulars, Tableau III., either in ledgers or as means, without indication of the plate from which each was derived).

These proposals were very kindly received by the Directors to whom they were addressed. The printed sheets were sent out in 1906 May, and were quickly filled up and returned. My sincere acknowledgments are due to the Directors of the Observatories of Bordeaux, Helsingfors, Northfield, San Fernando, and Toulouse, for the cordiality with which they undertook the troublesome task of filling in upon the printed sheets all the desired information; to the Astronomer Royal, who sent advance sheets of the Greenwich volume containing equivalent information; to the Director of the Pulkowa Observatory, who had previously given me similar material in advance of publication; and to the Director of the Paris Observatory, who furnished advance proofs of the Paris original measures.

The information thus obtained, added to that already published in full in the Paris Circulars for the *étoiles du carré de* 20′, gave me the completely separated results from a very large number of individual plates covering the path of the planet to 1900 December 31. (The discussion of the material for 1901 is postponed to a later date.)

§ 4. To make this considerable mass of material (about 60,000 star positions) homogeneous, I had first to find a way of reducing all the series to one fundamental system,[*] and to decide what this system should be.

In paper No. 4 I have given reasons for thinking that no one of those systems of fundamental star places based directly upon the meridian observations is satisfactory for our purpose. I decided to form a provisional system from photographic series which had

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[*] See *S.P.P.* No. 4, § 4, for the system to which each was originally reduced.

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been reduced to Loewy's system of meridian places. These series are compared in *S.P.P.* No. 5, p. 80, Table VI. It is there shown that the results from Greenwich and Paris are in excellent agreement; that the Toulouse places are nearly accordant with them; but that the Catania places differ from Paris in a large and irregular manner. I decided to omit the Catania results for the time, and to base the provisional photographic system of *repère* stars on a mean of Greenwich, Paris, and Toulouse.

The three observatories were given equal weight. A photographic place depending on 1 or 2 plates was given weight 1; on 3 to 6 plates, weight 2; and on 7 or more, weight 3. There would have been little advantage in adopting a more elaborate system of weights, since the real comparative weight of a result from one and from two plates depends very much upon the consideration whether or not the two plates are upon the same centre, and reduced with the same selection of fundamental stars.

We will call this system the System P.Ph. (provisional photographic).

The rôle of system P.Ph. is temporary. It serves to detect and eliminate systematic deviations between different observatories. It will be judged by the eventual degree of accordance between the reduced results when they are brought together for formation of the mean standard places. If this is satisfactory, we may consider that the system P.Ph. has played its part, and it may be allowed to disappear. We need not give, therefore, in this paper, the adopted places of the *repère* stars in the P.Ph. system, but may proceed at once to examine its use, and the effects of its use.

§ 5. The system P.Ph. is used as follows:—

We take differences between the places of the *repère* stars *derived from a single plate*, and their places in the system P.Ph. The mean of these differences, in the sense P.Ph.—plate, applied as a correction to the plate places of the *repère* stars, makes them conform on the average to the system P.Ph.

The same correction applied to all other star places deduced from this plate should reduce them equally to the system P.Ph., provided that there is no systematic discontinuity between *repère* stars and other stars.

The application of this correction produces in a general kind of way the same effect upon the star places as a re-reduction of the plate to the system P.Ph.; it leaves the results rougher in detail than a complete re-reduction, but nearly without those systematic errors which have been called Progressive discordances in *S.P.P.* No. 5, Tables VI. and VII.

§ 6. Corrections to be applied to individual plates were obtained in this way for the whole of the plates made at Bordeaux, Helsingfors, Northfield, San Fernando, and Toulouse. The following summary will give an idea of the size and distribution of these corrections.

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Table I.

Plate Corrections.

R.A. Corr.	Bord.	Hels.	North.	San Fern.		Toulouse.	
				Ord.	S.S.	Ord.	S.S.
	s	s	s	s	s	s	s
Greatest	+ ·015	+ ·027	+ ·021	+ ·023	+ ·034	+ ·017	+ ·017
Least	− ·010	+ ·002	− ·005	− ·017	− ·014	− ·009	− ·021
Mean	+ ·003	+ ·014	+ ·007	+ ·007	+ ·009	+ ·001	+ ·001
No. greater than + ·015 . .	0	16	4	8	6	1	2
between + ·015 and + ·006	10	15	26	30	18	4	7
+ ·005 and − ·005	21	5	17	19	15	5	22
− ·006 and − ·015	2	0	0	7	2	6	7
less than − ·015 . .	0	0	0	1	0	0	1

Decl. Corr.	Bord.	Hels.	North.	San Fern. Ord.	San Fern. S.S.	Toulouse Ord.	Toulouse S.S.
Greatest	+″·18	+″·06	+″·30	+″·30	+″·20	+″·10	+″·19
Least	− ·10	− ·08	− ·12	− ·02	− ·06	− ·06	− ·13
Mean	+ ·04	− ·01	·00	+ ·09	+ ·07	+ ·02	+ ·04
No. greater than +″·15 .	1	0	1	7	3	0	3
between + ·15 and + ·06	13	1	8	41	23	5	10
+ ·05 and − ·05	17	33	27	17	14	10	25
− ·06 and − ·15	2	2	11	0	1	1	1
less than − ·15 . .	0	0	0	0	0	0	0

The above figures show that the reduction to a system P.Ph. is by no means superfluous.

The fact that the mean correction for an entire series often differs considerably from zero may no doubt be attributed to divergence in the methods of combining and weighting the meridian results for the adopted *repère* star places.

The variations from plate to plate must be due partly to these divergences, and partly to the roughness of the meridian places compared with the smoothed system P.Ph.

Plate corrections for Catania, Greenwich, and Paris were not derived, because the separated results for each plate were not at the time available.* It seems certain, however, that it would have been superfluous to apply the process to the Greenwich and Paris series, which agree exceedingly well, and have preponderating weight in the formation of the system P.Ph. The absence of plate corrections for Catania is to be regretted, since large divergences occur in this series. (See *S.P.P. No.* 5, p. 84.)

§ 7. *Corrections for Magnitude Equation in the San Fernando and Toulouse Series.*—It was shown in *S.P.P.* No. 5, p. 78, that the Toulouse results have a large and nearly linear magnitude

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* The separated results for the Greenwich plates have since been communicated to me in proof, by the kindness of the Astronomer Royal.

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equation in declination (but none in right ascension). This result has been confirmed by M. Baillaud, Director of the Toulouse Observatory, but he has not succeeded in discovering the cause of it. (For this information I am indebted to M. Baillaud.)

It was shown in the same place that the San Fernando right ascensions and declinations were both affected by a considerable non-linear magnitude equation. No further light has been thrown on the cause of this error. Corrections were obtained by plotting the results for successive magnitude groups (*loc. cit.*), and drawing the best possible smooth curves through them. The quantities derived from these curves were adjusted to allow for the fact that a general mean correction for stars of all magnitudes resulted from the application of the plate corrections of Table I.: the quantity 0″·03 was subtracted from the Toulouse corrections, and $0^{\mathrm{s}}{\cdot}007$, 0″·08 from the respective San Fernando corrections. The final magnitude corrections applicable to Toulouse and San Fernando are given in condensed form in the following table :—

Table II.

Adopted Corrections for Magnitude Equation.

	Toulouse.	San Fernando.	
	Decl.	R.A.	Decl.
Mag.	″	s	″
7·0	−0·23	+0·011	−0·21
7·5	− 15	+ 6	− 12
8·0	− 8	+ 2	− 6
8·5	0	− 2	+ 2
9·0	+ 8	− 2	+ 8
9·5	+ 15	+ 2	+ 12
10·0	+ 23	+ 6	+ 15
10·5	+ 31	+ 12	+ 15
11·0	+ 38	+ 18	+ 15
11·5	+ 46	+ 24	+ 14
12·0	+ 54	+ 32	+ 10

§ 8. *Collection of material for formation of catalogue.*—The individual star places published in Paris Circulars 10–12, or communicated to me in manuscript upon the printed forms sent out from Cambridge, were entered on catalogue cards, differently coloured for each observatory. These will be referred to as "detail cards."

The plate corrections and the magnitude equation corrections were applied on the detail cards, and "observatory means" were formed.

Whenever a star had been observed at more than one observatory, a "summary card" was added to the card catalogue on which the observatory means were collected, and the final weighted mean taken.

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§ 9. *The System of Weights.*—The summary cards showed at once that the observatories were not entitled to equal weight. At the same time it was not possible to derive a rigorous system of weights from a discussion of the divergences between one observatory and another, or between the individual results of an observatory. These divergences were necessarily much affected by the fact that five or six separate determinations of a star place made at one observatory would depend on the same set of *repère* stars, and be on the same part of the plate, whereas the same star would be determined elsewhere on a different centre.

After some trial it appeared that substantial justice would be done if Greenwich and Paris were given a weight double that of the other observatories, and if the weight of each observatory's contribution, so far as it depended upon the number of observations contributed by each, were on the same scale as was used in making the system P.Ph. of § 4.

Two Catania plates and one San Fernando were rejected for unexplained systematic discordance of large amount; a certain number of obvious misprints in the Circulars were corrected, and a few discordant observations, probably misprints, were excluded.

Finally, stars whose weighted mean had weight 4 or more were passed into a first class, and these form the photographic standard system discussed in what follows. In the region covered by the planet between 1900 Oct. 1 and Dec. 31 the catalogue contains 1300 first class stars. And in addition there are about 2500 stars in a second class, whose weight is less than 4, which are not for the present included in the standard system.

§ 10. *Test of the Standard System.*—As a test of the homogeneity of the contributions which the different observatories make to the standard system, I have discussed the differences, Standard minus Individual contribution to it, from several points of view.

A. The differences, taken with regard to sign, have been grouped (1) in magnitude groups, to see if any residual magnitude equation remained; and (2) in date groups, to see if there were any discontinuity along the path of the planet which might gradually distort the standard system, and damage an ultimate determination of the mass of the Moon.

B. The differences, taken without regard to sign, have been grouped likewise (1) in magnitude groups, to see how far the interagreement of the photographic places is dependent on magnitude; and (2) in date groups, to see if the same standard of internal agreement is maintained along the whole system.

The magnitude groups are those used in *S.P.P.* No. 5, Tables III., IV., and V.

The date groups are broader than those used in Table VII. (*loc. cit.*).

Group	I.	covers	Sept. 15–Oct. 23
,,	II.	,,	Oct. 24–Nov. 24
,,	III.	,,	Nov. 25–Dec. 15
,,	IV.	,,	Dec. 15–Dec. 31

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There is no special significance in this particular division, which arose more or less accidentally, and has been retained for convenience.

§ 11. *Search for Magnitude Equation in R.A.*—The division into magnitude groups of the differences Standard minus Individual contribution was made separately for the four date groups. But there is no evidence in the results of any definite change of magnitude equation with the date; if any such change exists, it is obscured by the accidental discordances. Consequently I give only the mean results for the whole period Oct.–Dec., except in the case of San Fernando, to which a correction for magnitude equation has been applied. The separate results for each San Fernando date group are given.

The figures in brackets are the numbers of observatory means contributing to the mean discordances which follow.

Table III.

Comparison of Right Ascensions in Magnitude Groups.

Standard System minus—

	Bordeaux.	**Catania.**	**Greenwich.**	**Helsingfors.**	**Northfield.**
Mag.	s	s	s	s	s
− 7·4	(14) − ·007	(78) − ·004	(32) ·000	(12) + ·015	(24) + ·012
7·5 − 8·4	(43) − 1	(66) + 3	(73) − 1	(57) + 4	(59) + 3
8·5 − 9·2	(99) 0	(55) + 6	(125) − 1	(75) − 5	(89) − 4
9·3 − 9·8	(48) − 3	(50) + 8	(32) + 2	(89) − 3	(10) − 3
9·9 − 10·5	(131) − 2	(72) + 7	(27) − 5	(117) − 8	...
10·6 − 11·2	(53) − 4	(118) + 3	(5) − 1	(99) − 5	...
11·3 − 12·1	(6) − 15	(167) + 1	(3) − 8	(7) + 6	...
12·2 −	...	(21) − 4	...	...	...

	Paris.	**Pulkowa.**	**Toulouse.**	**Upsala.**	**Minneapolis.**
	s	s	s	s	s
− 7·4	(47) + ·003	(7) + ·002	(33) − ·003	(15) + ·016	(8) + ·011
7·5 − 8·4	(70) − 1	(22) + 2	(124) + 3	(43) + 6	(17) + 3
8·5 − 9·2	(71) 0	(27) + 1	(229) + 4	(111) + 1	(38) + 2
9·3 − 9·8	(60) − 3	(5) + 10	(99) + 3	(68) − 1	(38) − 13
9·9 − 10·5	(103) + 1	...	(179) + 5	(84) − 1	(49) − 1
10·6 − 11·2	(124) + 2	...	(147) + 8	(33) − 6	(25) − 7
11·3 − 12·1	(193) + 2	...	(49) + 7	(5) − 3	(9) − 15
12·2 −	(267) + 2	...	...	...	(2) − 16

	S. Fern. Group I.	**S. F. II.**	**S. F. III.**	**S. F. IV.**	**S. F. Mean.**
	s	s	s	s	s
− 7·4	(19) − ·002	(16) − ·012	(4) − ·002	(15) − ·008	(54) − ·007
7·5 − 8·4	(35) + 3	(31) + 4	(9) + 9	(28) + 1	(103) + 3
8·5 − 9·2	(67) + 4	(72) + 2	(42) + 4	(52) + 1	(233) + 2
9·3 − 9·8	(21) + 11	(33) + 2	(21) − 4	(14) + 8	(89) + 4
9·9 − 10·5	(40) + 3	(63) + 11	(29) + 5	(14) − 2	(146) + 6
10·6 − 11·2	(46) 0	(79) − 1	(12) − 3	(8) − 10	(145) − 1
11·3 − 12·1	(8) − 6	(40) + 2	...	(3) − 13	(52) − 1
12·2 −	(7) − 2	...	...	...	(8) 0

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The results of this table confirm the conclusion of *S.P.P.* No. 5, that the photographic series which contribute to the standard system are free from relative magnitude equation, with the exception of San Fernando.

The latter observations have been corrected, and we can now see how far this correction has been successful. The correction applied was decidedly non-linear; the above comparison gives some indication that a slight non-linear correction of opposite curvature is now required; that is to say, that the curvature of the original determination was a little excessive. (The material used was not altogether the same.) The magnitude equation results from the separate date groups are not, however, accordant enough to make it probable that any magnitude equation correction for San Fernando is sharply determinable; and we may conclude that the attempt to correct these R.A.'s has been as successful as the material allows.

The Upsala and Minneapolis results were not published in time to be included in the first edition of the standard system. But they show no magnitude equation when compared with it, and may therefore be included safely on a revision.

§ 12. *Search for Magnitude Equation in Declination.*—The declinations have been treated exactly as the right ascensions. Again there is no trace of any definite change of magnitude equation with the date, and the general means are free from it. The corrections applied to the declinations of San Fernando and Toulouse seem to have been successful in eliminating the large errors originally found in them. Table IV. gives the results for the date groups in which the elimination has been least successful, and for the mean.

The lately published declinations of Upsala and Minneapolis show no magnitude equation relative to the standard system.

Table IV.

Comparisons of Declinations in Magnitude Groups.

Standard System minus—

Mag.	**Bordeaux.**	**Catania.**	**Greenwich.**	**Helsingfors.**	**Northfield.**
– 7·4	(14)+″·06	(78)+″·06	(32)+″·01	(12)+″·02	(23)–″·03
7·5 – 8·4	(43) – 1	(67) 0	(73) – 1	(57) + 5	(59) + 1
8·5 – 9·2	(99) + 1	(57) + 4	(125) + 2	(73) – 1	(89) 0
9·3 – 9·8	(48) + 1	(50) – 3	(32) + 4	(89) 0	(10) – 5
9·9 – 10·5	(131) 0	(74) + 2	(27) + 3	(117) – 2	...
10·6 – 11·2	(53) – 4	(118) + 3	(5) – 3	(99) – 3	...
11·3 – 12·1	(6) – 3	(177) – 6	(3) 0	(7) – 6	...
12·2 –	...	(22) – 11	...	...	...

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Table IV.—*continued.*

Comparisons of Declinations in Magnitude Groups.

Standard System minus—

	Paris.	Pulkowa.	S. Fern. III.	S. Fern. IV.	S.F. Mean.
− 7·4	(47) − ″·06	(7) − ″·02	(4) + ″·03	(15) + ″·07	(54) + ″·05
7·5 − 8·4	(70) − 3	(22) + 2	(9) + 6	(28) + 1	(103) + 4
8·5 − 9·2	(71) + 4	(27) 0	(42) + 10	(52) + 5	(233) + 1
9·3 − 9·8	(60) − 3	(5) − 5	(21) + 8	(14) + 9	(89) + 2
9·9 − 10·5	(103) − 2	...	(29) + 5	(14) + 8	(147) + 3
10·6 − 11·2	(123) − 3	...	(12) + 37	(8) + 19	(146) + 8
11·3 − 12·1	(193) − 2	...	...	(3) + 24	(54) + 4
12·2 −	(267) + 1	...	...	...	(8) − 2

	Toul. II.	Toul. III.	Toul. Mean.	Upsala.	Minneapolis.
− 7·4	(9) + ″·13	(9) + ″·07	(33) + ″·05	(15) + ″·06	(8) − ″·05
7·5 − 8·4	(40) − 1	(18) + 3	(124) + 1	(43) + 3	(17) + 9
8·5 − 9·2	(71) − 1	(41) − 9	(229) − 2	(111) + 2	(38) − 1
9·3 − 9·8	(30) + 5	(19) − 7	(97) + 1	(68) + 6	(38) + 3
9·9 − 10·5	(76) + 1	(39) − 1	(179) + 2	(84) + 1	(48) + 9
10·6 − 11·2	(51) − 5	(20) − 17	(147) − 3	(33) + 1	(25) − 5
11·3 − 12·1	(17) − 9	(9) − 21	(49) − 7	(5) + 41	(9) + 9
12·2 −	...	...	...	...	(2) + 10

§ 13. *Conclusion as to Photographic Magnitude Equation.*—As the result of our operations, we have a system of stars derived from photographs made at nine different observatories; and the comparison of each series with the mean shows no relative magnitude equation.

Further, two additional series, not originally included, show no magnitude equation relative to the system.

It is extremely unlikely that these eleven series should be affected by magnitude equation of like sign and amount.

I conclude that our photographic standard system is sensibly free, not only from relative, but from absolute magnitude equation.

§ 14. *Search for Progressive or Uniform Discordances irrespective of Magnitude.*—With the fear of magnitude equation removed, we may examine the mean divergences in the date groups, to see if there is any evidence of progressive or general discordance. The tables which follow are self-explanatory.

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Table V.

Comparison of Right Ascensions, in Date Groups.

Standard System minus—

Group	Bordeaux.	Catania.	Greenwich.	Helsingfors.	Northfield.
	s	s	s	s	s
I. Sept. 15–Oct. 23	(117) − ·004	(176) + ·001	(70) − ·002	(76) − ·003	(35) + ·001
II. Oct. 24–Nov. 24	(163) − 3	(290) + 2	(104) 0	(154) − 4	(57) − 1
III. Nov. 25–Dec. 15	(42) − 2	(100) + 9	(52) + 1	(145) − 3	(36) 0
IV. Dec. 16–Dec. 31	(73) − 1	(61) − 1	(71) − 3	(81) − 3	(54) + 1
Mean	(395) − 2	(627) + 3	(297) − 1	(456) − 3	(182) 0

	Paris.	Pulkowa.	San Fern.	Toulouse.	Upsala.	Minneapolis.
	s	s	s	s	s	s
I.	(243) + ·003	...	(243) + ·002	(216) + ·002	(39) − ·002	(42) − ·004
II.	(390) 0	(14) + ·004	(334) + 2	(295) + 9	(149) − 3	(69) − 4
III.	(129) 0	(32) + 4	(118) + 2	(156) + 2	(97) + 18	(33) − 2
IV.	(173) + 2	(15) − 4	(135) − 1	(194) + 2	(74) − 13	(42) − 4
Mean	(935) + 1	(61) + 2	(830) + 2	(861) + 4	(359) + 1	(186) − 4

Table VI.

Comparison of Declinations, in Date Groups.

Standard System minus—

Group	Bordeaux.	Catania.	Greenwich.	Helsingfors.	Northfield.
	″	″	″	″	″
I. Sept. 15–Oct. 23	(117) ·00	(176) − ·05	(70) + ·01	(74) + ·01	(35) + ·02
II. Oct. 24–Nov. 24	(163) − 2	(307) − 2	(104) + 1	(154) − 3	(57) + 1
III. Nov. 25–Dec. 15	(42) + 1	(100) + 1	(52) + 2	(145) − 1	(35) 0
IV. Dec. 16–Dec. 31	(73) + 3	(60) + 16	(71) 0	(81) + 1	(54) − 2
Mean	(395) 0	(643) 0	(297) + 1	(454) − 1	(181) 0

	Paris.	Pulkowa.	San Fern.	Toulouse.	Upsala.	Minneapolis.
	″	″	″	″	″	″
I.	(243) − ·02	...	(243) + ·03	(216) + ·01	(39) + ·09	(42) + ·08
II.	(390) + 1	(14) + ·01	(338) + 1	(294) − 1	(149) − 1	(69) − 2
III.	(129) − 2	(32) 0	(118) + 11	(155) − 6	(97) + 3	(32) + 6
IV.	(172) − 5	(15) − 3	(135) + 6	(194) + 2	(74) + 8	(42) + 4
Mean	(934) − 1	(61) 0	(834) + 4	(859) − 1	(359) + 3	(185) + 3

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It is clear that no series has now any sensible uniform discordance from the mean. And the results from the separate date groups are nearly concordant, so that it seems out of the question that the standard system has been seriously distorted in any part by the inclusion of discordant material. The only marked cases of discordance are in Catania group III. and Toulouse group II. We shall have occasion to examine these in a later paper.

§ 15. *Effect of the application of Plate Corrections.*—We may look in the above table for the effect of the application of the plate corrections of § 6. The largest corrections were found for Helsingfors, Northfield, and San Fernando plates.

The Helsingfors plates received on the average corrections of $+{}^{s}\cdot014$, $-{}''\cdot01$ (derived from *repère* stars); the results, including all stars, are now discordant from the standard system by $-{}^{s}\cdot003$, $-{}''\cdot01$.

The Northfield plates received on the average corrections of $+{}^{s}\cdot007$, ${}''\cdot00$; the results are now discordant from the standard system by ${}^{s}\cdot000$, ${}''\cdot00$.

The San Fernando plates received on the average corrections of $+{}^{s}\cdot008$, $+{}''\cdot08$; they are now discordant from the standard system by $+{}^{s}\cdot002$, $+{}''\cdot04$.

In these cases the application of plate corrections has very much reduced the general discordance.

For Bordeaux and Toulouse the mean plate correction was small, and the mean discordance from the standard system remains small.

The discordances of the series to which no plate corrections were applied are also, fortunately, small. We may conclude that the application of the plate corrections has been successful in eliminating such mean discordances between the different series as were sensible.

§ 16. *Influence of Magnitude on the Accuracy of the Photographic Star Places.*

Many of the star images measured upon these plates are at the limit of measurability; and in many cases, by reason of thick skies or unduly short exposures, the images of the planet also are only just measurable. It is therefore very necessary to determine whether the accuracy of the photographic places is seriously impaired when the images are very faint.

To examine this point I have tabulated the average discordances (without regard to sign) of each observatory's series from the standard system. Since the mean discordances are very small, the average discordances will give a fair idea of the relative accuracy of the star places for different magnitudes and for different series.

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Table VII.

Average Discordance of Right Ascensions, in Magnitude Groups.

Standard System minus—

Mag.	Bordeaux.		Catania.		Greenwich.		Helsingfors.		Northfield.	
		s		s		s		s		s
− 7·4	(14)	·014	(78)	·026	(32)	·011	(12)	·019	(24)	·021
7·5 − 8·4	(43)	12	(66)	16	(73)	9	(57)	18	(59)	13
8·5 − 9·2	(99)	11	(55)	22	(125)	7	(75)	17	(89)	14
9·3 − 9·8	(48)	9	(50)	17	(32)	8	(89)	16	(10)	25
9·9 − 10·5	(131)	13	(72)	23	(27)	7	(117)	23	...	
10·6 − 11·2	(53)	9	(118)	21	(5)	6	(99)	23	...	
11·3 − 12·1	(6)	15	(167)	23	(3)	8	(7)	27	...	
12·2 −	...		(21)	22	...		...		...	

Paris.		Pulkowa.		San Fernando.		Toulouse.		Upsala.		Minneapolis.	
			s		s		s		s		s
(47)	·012	(7)	·010	(54)	·015	(33)	·015	(15)	·030	(8)	·030
(70)	9	(22)	14	(103)	17	(124)	18	(43)	15	(17)	26
(71)	9	(27)	13	(233)	15	(229)	16	(111)	17	(38)	21
(60)	9	(5)	17	(89)	21	(99)	14	(68)	20	(38)	19
(103)	8	...		(146)	24	(179)	18	(84)	21	(49)	21
(124)	12	...		(145)	26	(147)	18	(33)	27	(25)	22
(193)	12	...		(52)	24	(49)	19	(5)	27	(9)	34
(267)	11	...		(8)	19	...		...		(2)	16

Table VIII.

Average Discordance of Declinations, in Magnitude Groups.

Standard System minus—

Mag.	Bordeaux.		Catania.		Greenwich.		Helsingfors.		Northfield.	
		″		″		″		″		″
− 7·4	(14)	·17	(78)	·27	(32)	·09	(12)	·19	(23)	·21
7·5 − 8·4	(43)	10	(67)	22	(73)	8	(57)	19	(59)	10
8·5 − 9·2	(99)	9	(57)	21	(125)	7	(73)	16	(89)	13
9·3 − 9·8	(48)	10	(50)	17	(32)	6	(89)	12	(10)	16
9·9 − 10·5	(131)	11	(74)	20	(27)	8	(117)	16	...	
10·6 − 11·2	(53)	11	(118)	18	(5)	3	(99)	20	...	
11·3 − 12·1	(6)	9	(177)	20	(3)	9	(7)	29	...	
12·2 −	...		(22)	27	...		...		...	

Paris.		Pulkowa.		San Fernando.		Toulouse.		Upsala.		Minneapolis.	
	″		″		″		″		″		″
(47)	·09	(7)	·07	(54)	·17	(33)	·21	(15)	·18	(8)	·33
(70)	10	(22)	9	(103)	14	(124)	16	(43)	13	(17)	19
(71)	10	(27)	8	(233)	15	(229)	16	(111)	13	(38)	20
(60)	10	(5)	17	(89)	17	(97)	14	(68)	17	(38)	17
(103)	9	...		(147)	22	(179)	18	(84)	19	(48)	21
(123)	10	...		(146)	27	(147)	19	(33)	21	(25)	22
(193)	12	...		(54)	24	(49)	22	(5)	45	(9)	22
(267)	12	...		(8)	17	...		...		(2)	22

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In comparing these results we must remember that Greenwich and Paris have received double weight, and that they will naturally therefore diverge less from the mean than the others. We must also remember that the fainter stars have on the average fewer observations than those of moderate brightness; and no account has been taken of the number of observations for each star at each observatory in making the above comparisons. Nevertheless, the apparent accuracy of the fainter stars falls off very little, except in the case of Helsingfors and San Fernando. The latter series was measured in one orientation only, which may account for much. A more detailed discussion of the Helsingfors series will be given in a later paper, which may help to explain this result.

The general conclusion, that the accuracy of the very faint star places is little inferior to that of the brighter, is as welcome as it is unexpected.

§ 17. *Comparative and Absolute Accuracy of the results from different Observatories.*—Since it has been shown in the last paragraph that magnitude has small influence on accuracy, we may combine the material into date groups without inquiring closely whether the mean magnitude is the same in each group, and may thus discover whether the same accuracy was achieved at different dates, in different parts of the planet's path. And we may further examine whether the rough system of weights adopted fairly represents the relative merits of the results from different observatories.

Table IX.

Average Discordance of Right Ascensions, in Date Groups.

Standard System minus—

Group	Bordeaux.		Catania.		Greenwich.		Helsingfors.		Northfield.	
		s		s		s		s		s
I. Sept. 15–Oct. 23	(117)	·010	(176)	·020	(70)	·007	(76)	·025	(35)	·011
II. Oct. 24–Nov. 24	(163)	13	(290)	23	(104)	7	(154)	25	(57)	18
III. Nov. 25–Dec. 15	(42)	12	(100)	22	(52)	8	(145)	14	(36)	19
IV. Dec. 16–Dec. 31	(73)	10	(61)	18	(71)	10	(81)	16	(54)	12
Mean	(395)	11	(627)	22	(297)	8	(456)	20	(182)	15

	Paris.		Pulkowa.		San Fern.		Toulouse.		Upsala.		Minneapolis.	
		s		s		s		s		s		s
I.	(243)	·009	...		(243)	·019	(216)	·015	(39)	·014	(42)	·019
II.	(390)	11	(14)	·011	(334)	22	(295)	21	(149)	20	(69)	21
III.	(129)	13	(32)	15	(118)	21	(156)	16	(97)	25	(33)	32
IV.	(173)	10	(15)	12	(135)	16	(194)	13	(74)	18	(42)	19
Mean	(935)	11	(61)	13	(830)	20	(861)	17	(359)	20	(186)	22

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Table X.

Average Discordance of Declinations, in Date Groups.

Standard System minus—

Group	Bordeaux.		Catania.		Greenwich.		Helsingfors.		Northfield.	
I. Sept. 15–Oct. 23	(117)	″·10	(176)	″·23	(70)	″·07	(74)	″·18	(35)	″·11
II. Oct. 24–Nov. 24	(163)	12	(307)	·18	(104)	8	(154)	19	(57)	12
III. Nov. 25–Dec. 15	(42)	11	(100)	·21	(52)	6	(145)	13	(35)	14
IV. Dec. 16–Dec. 31	(73)	10	(60)	·27	(71)	8	(81)	18	(54)	14
Mean	(395)	11	(643)	·21	(297)	8	(454)	17	(181)	13

	Paris.		Pulkowa.		San Fern.		Toulouse.		Upsala.		Minneapolis.	
I.	(243)	″·10	...	″	(243)	″·17	(216)	″·16	(39)	″·19	(42)	″·20
II.	(390)	10	(14)	·06	(338)	20	(294)	18	(149)	16	(69)	18
III.	(129)	15	(32)	11	(118)	21	(155)	19	(97)	18	(32)	20
IV.	(172)	11	(15)	9	(135)	18	(194)	16	(74)	15	(42)	25
Mean	(934)	11	(61)	9	(834)	19	(859)	17	(359)	17	(185)	21

We may draw the following conclusions from these tables:—

The concordance of the observations is fairly uniform along the path of the planet, though there are considerable exceptions in the R.A.'s from Helsingfors, Minneapolis, Toulouse, and Upsala.

The Greenwich and Paris places were fully entitled to the double weight which they received.

The Bordeaux places might also have received double weight.

The Northfield and Pulkowa places might have been given some extra weight. But as they are chiefly well-observed *repère* stars, the effect upon the standard system would have been small in any case.

Judged by their average discordance, the Catania and San Fernando places are barely entitled to the unit weight which they received. Attention has already been called to very large and irregular discordances in the former series (*S.P.P.* No. 5, p. 84). The San Fernando plates have generally only a single exposure, measured in a single orientation, whereas other observatories usually have three or four exposures, measured in at least two orientations.

A second of time is equivalent to ten seconds of arc in declination 48°, which is close to the mean declination of the stars in our standard system. A comparison of the figures in the above table shows that the right ascensions and declinations are very closely of the same average accuracy.

§ 18. *Probable Error of the Standard System.*—To obtain from the above discussed discordances an exact estimate of the probable error of a star place in our standard system would be very laborious, if not impracticable, and the labour is not warranted in the present stage of the work.

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We may, however, estimate the probable error roughly, as follows:—

The average discordance of the contributions to which unit weight has been given is well under 0″·20. A majority of these depend upon one or two observations, and have received weight 1. The probable error of a contribution of weight 1 is likely to be not greater than 0″·20, probably less. And a star is not admitted to the standard system unless its weight is at least 4, while the average weight is 7 or 8. The probable error of a standard place in each co-ordinate will therefore be well under 0″·10, but how much under it is impossible to say at present.

§ 19. *The use of the Standard System.*—The standard system provides fairly completely for the reduction of the Crossley Reflector plates, furnishing from 8 to 12 comparison stars along a good part of the planet's path. These star places have been already communicated to Professor Perrine. There are thin places in the catalogue, due to bad weather in Europe while it was fine at Mount Hamilton; these must be filled up if possible. By the kindness of the Astronomer Royal, a considerable part of the material required has been already supplied from special measures made on Greenwich plates, which are not included in the above discussion.

The catalogue also provides for the complete reduction of the Cambridge, Oxford, and Tashkend series, and any others that may be outstanding.

Further, I propose to try the effect of making the equivalent of a re-reduction of the published photographic places, in the following way:—

The programme of Monsieur Loewy included the measurement of all stars in a square of 20′, having the planet at its centre; these were reduced and published separately for each plate. The "*carré de vingt minutes*" generally contains six or eight of our standard system stars, sometimes as many as twenty, and we can compare the individual plate places with those in the standard system. If anything abnormal has happened to the plate, either in making or in reduction, the effect upon the mean of a group of stars scattered over the square would be very nearly the same as upon the planet at its centre. And if we apply to the planet's place a correction derived from the mean difference Standard System minus Stars of the Square, it seems that we ought to get rid of any troubles of a systematic nature in a very simple way.

Suppose, for example, that one telescope has an optical distortion that displaces the centre of the plate with respect to its edges; that another has an optical distortion that skews the plate and makes the scale value in x and y sensibly different, so that there is a large and systematic difference between a six constant and a four constant linear reduction; suppose that a third observatory has used a quite wrong expression in calculating the second order refraction corrections; and that in the work of a fourth the errors in the solution of the plate are undesirably common,—and these suppositions are not so extravagant as they may appear,—the simple

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process of reduction to the standard system by means of the stars in the 20′ square will avoid the systematic effects of all these untoward circumstances, and will give a result equivalent to, though not so smooth as, a complete re-reduction.

The standard system will also be indispensable for the reduction of the micrometric comparisons of the planet. In Paris Circulars 8 and 9 Monsieur Loewy published a list of stars used in these comparisons, and desired that they should be measured on the photographs whenever possible. As a result of this, the standard catalogue contains good places of a very large majority of these stars, and provides almost completely for the reduction of most of the micrometer series. The only serious difficulty may be found in reducing the observations made at Washington and Yerkes Observatories, where they used some stars so faint that they are not found on the ordinary photographs. These stars were all marked on charts sent to Professor Perrine for use in selecting his comparison stars, and he has succeeded in finding and measuring a large part of them on the Crossley plates.

We have therefore reason to hope that this standard photographic system of stars may provide, directly or indirectly, for the complete reduction of the Eros observations of 1900 on a homogeneous system.

The extension of the system to the early months of 1901 is making excellent progress.

§20. As before, the additional assistance required in this work has been provided by a grant from the Government Grant Fund of the Royal Society.

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